

# **MIPP** The MIPP experiment and its application to neutrino beam simulations

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on behalf of the MIPP Collaboration:  
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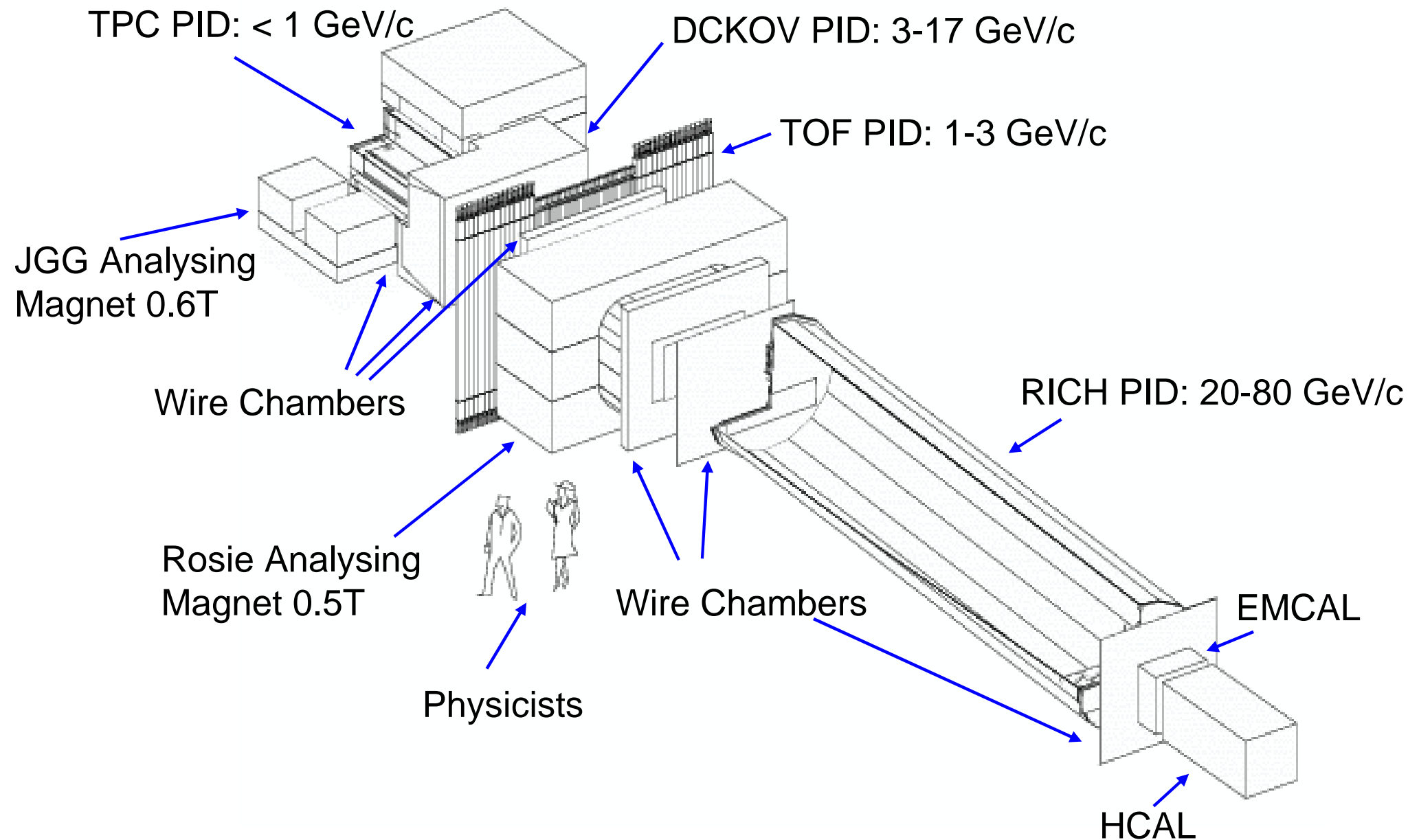
APS Dallas, TX  
April 2006



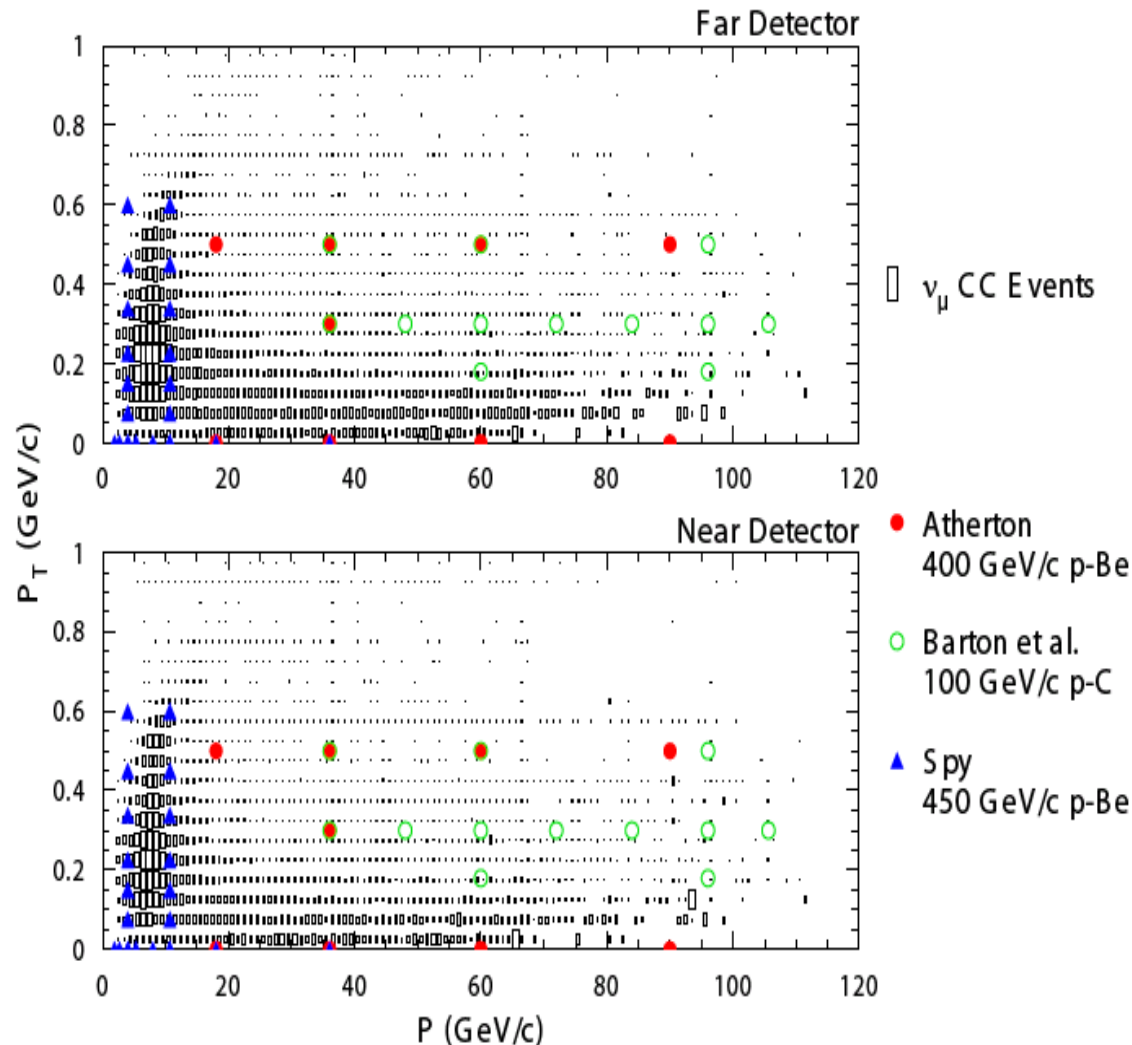
# MIPP overview

- Measure particle production off various nuclei
- Incoming beam of  $\pi^\pm$ ,  $K^\pm$  and  $p^\pm$  from 5 to 80 GeV/c and primary p beam from the Main Injector
- Large acceptance spectrometer including a Time Projection Chamber
- Example physics topics
  - Hadronic fragmentation – test scaling law of particle fragmentation
  - Light meson spectroscopy
  - Nuclear scaling, strangeness production
  - Proton radiography
  - Neutrino physics – more later

# The MIPP Spectrometer



# Application to neutrino experiments



Distribution of hadrons decaying to produce neutrinos at the MINOS near and far detectors

- Hadron production is largest uncertainty in neutrino flux prediction
- Existing hadron production data sparse
- Measure production from NuMI target
- Use event by event measurement as input to NuMI beam simulator (replace Fluka target)
- Also thin C, Al and Be targets
- Combine thin and thick target data to benchmark cascade calculations in thick targets

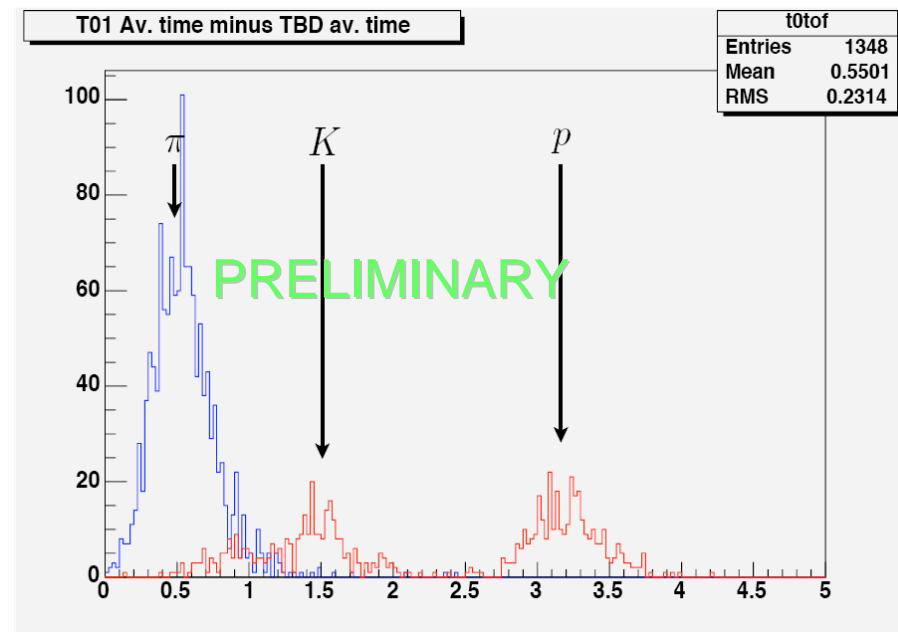
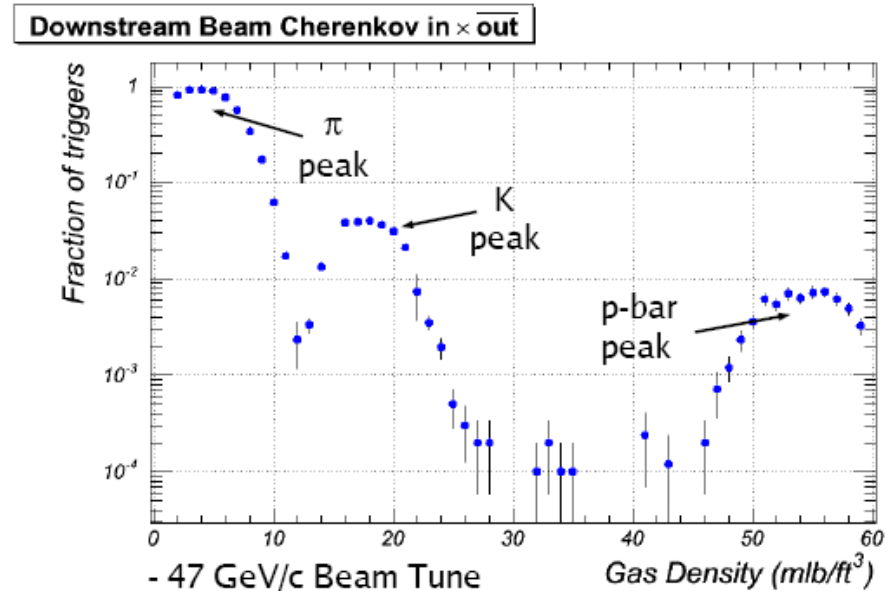
# Data collected

- Ran throughout 2005 and first two months of 2006
- 5 thin targets Be, C, Al, Bi, U
- 7 million Liquid Hydrogen events
- 1.78 million events on the NuMI target
- 14 million events with no TPC (faster data rate) for Kaon mass measurement from RICH ring diameter
- First reconstruction pass completed – DST produced for analyses

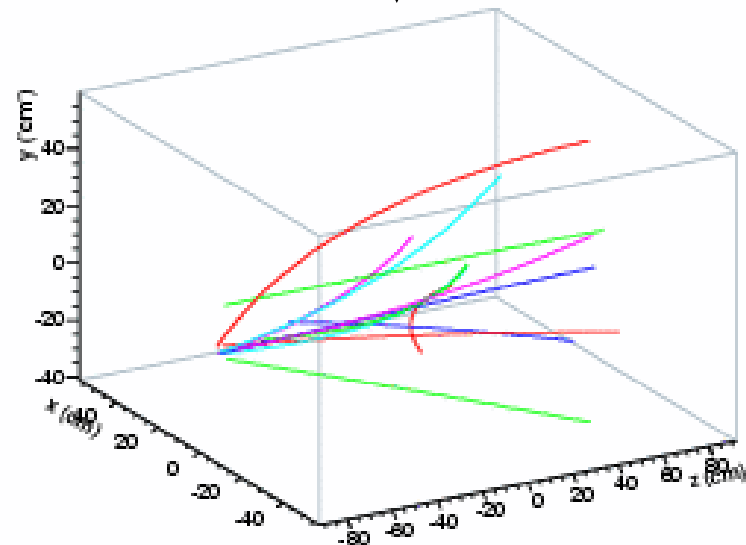
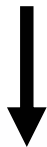
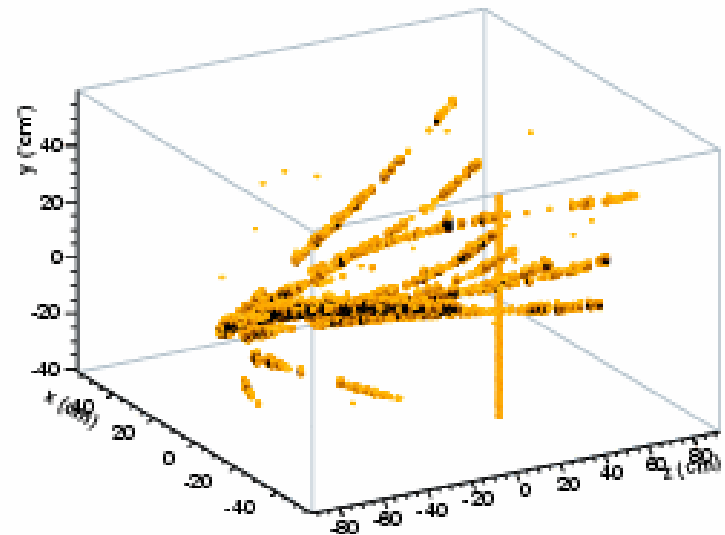
Data Summary 27 February 2006			Acquired Data by Target and Beam Energy									
			Number of events, $\times 10^6$									
Target			E GeV/c									Total
Z	Element	Trigger Mix	5	20	35	40	55	60	65	85	120	
0	Empty <sup>1</sup>	Normal		0.10	0.14			0.52			0.25	1.01
	K Mass <sup>2</sup>	No Int.				5.48	0.50	7.39	0.96			14.33
	Empty LH <sup>1</sup>	Normal		0.30				0.61		0.31		7.08
1	LH	Normal	0.21	1.94				1.98		1.73		
4	Be	<i>p</i> only									1.08	1.75
		Normal			0.10			0.56				
6	C	Mixed						0.21				1.33
	C 2%	Mixed		0.39				0.26			0.47	
	NuMI	<i>p</i> only								1.78		1.78
13	Al	Normal		0.10								0.10
83	Bi	<i>p</i> only								1.05		2.83
		Normal		0.52				1.26				
92	U	Normal						1.18				1.18
Total			0.21	2.73	0.86	5.48	0.50	13.97	0.96	2.04	4.63	31.38

# Beam particle ID and trigger

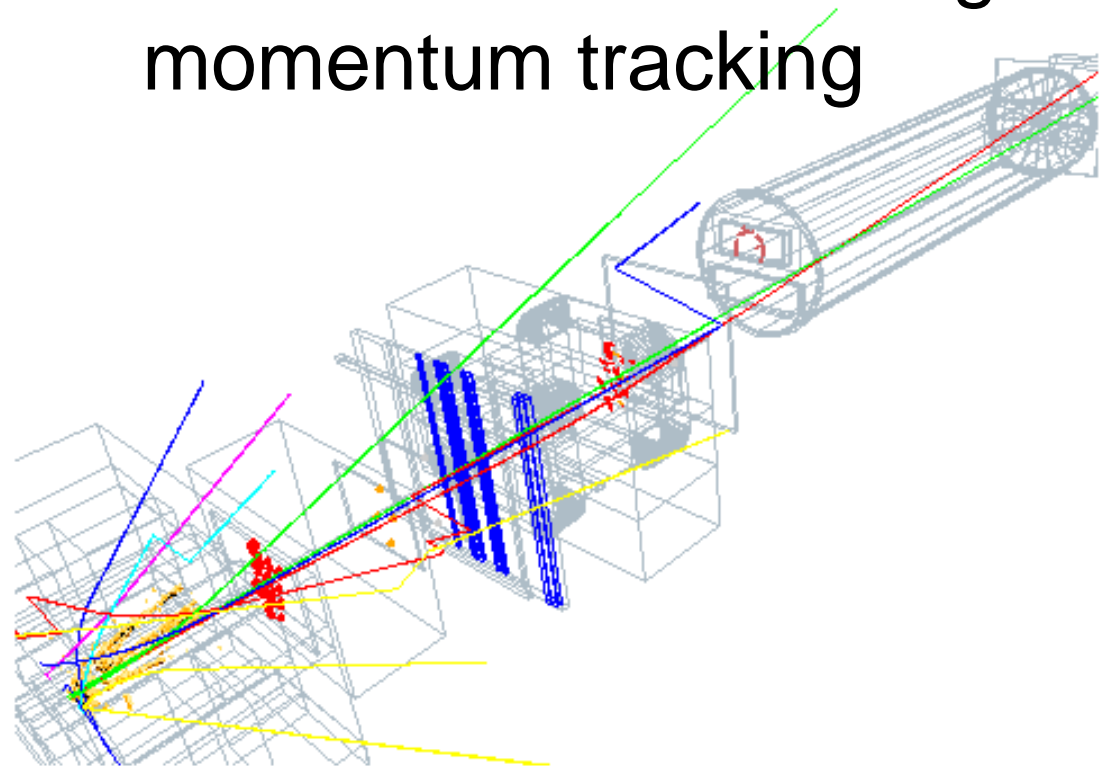
- Need to tag incoming particle, use two upstream Cerenkov detectors
- >85% purity (tested with RICH)
- Can use beam TOF for 5 GeV/c
- Added small scintillator trigger behind thin targets
- Combined with multiplicity in first drift chamber
- Purpose built scintillator trigger for NuMI target



# TPC and tracking



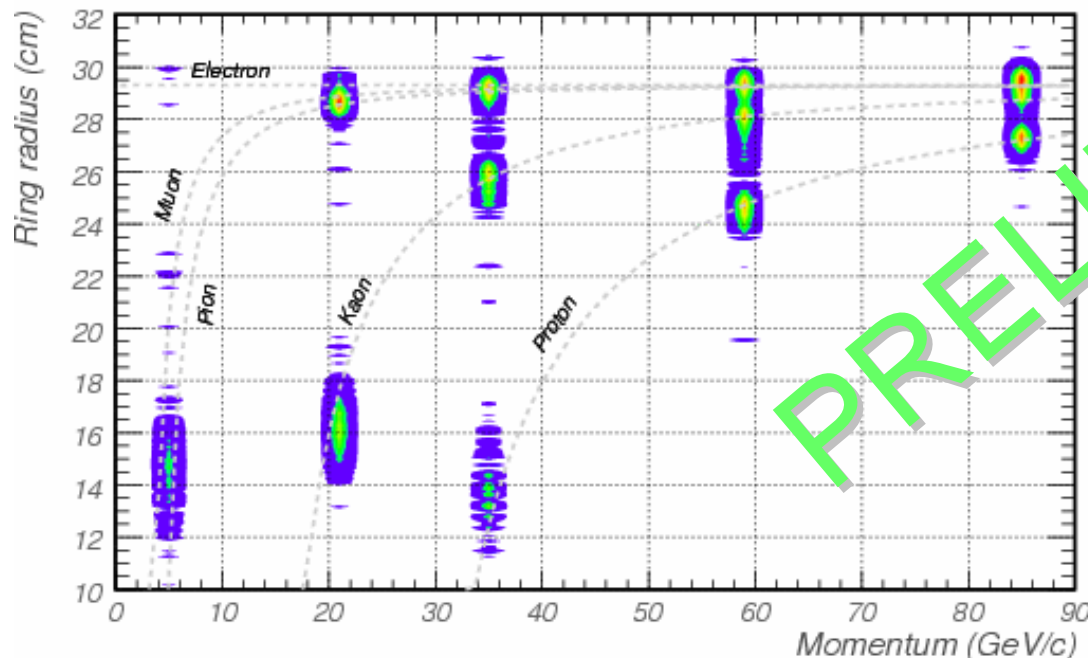
- Raw TPC data, form clusters of hits in Z slices, then form tracks and vertex
- 6 wire chambers for high momentum tracking



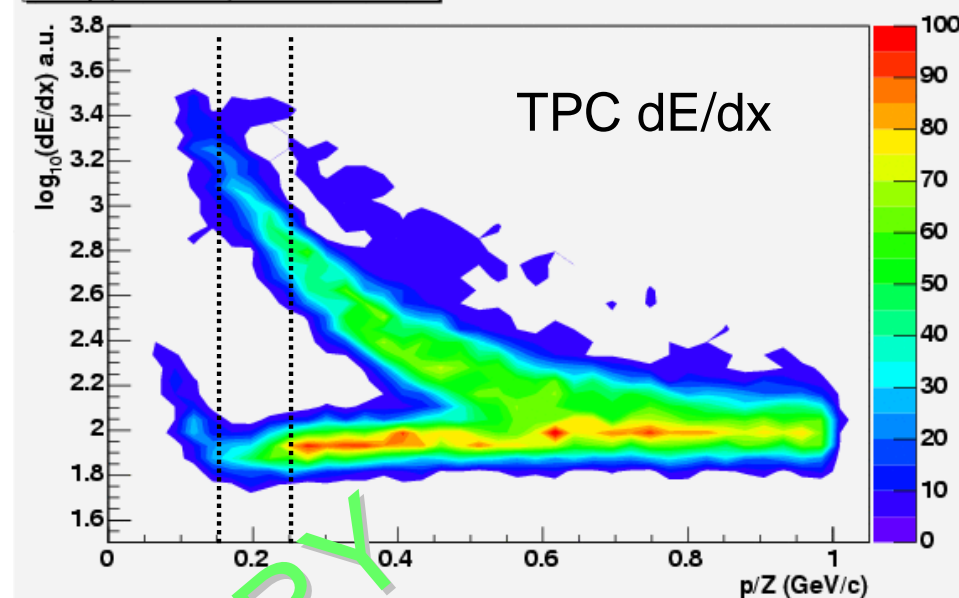
# Particle ID

- TPC dE/dx already shows good Pi/K/P separation
- RICH particle ID also in good condition

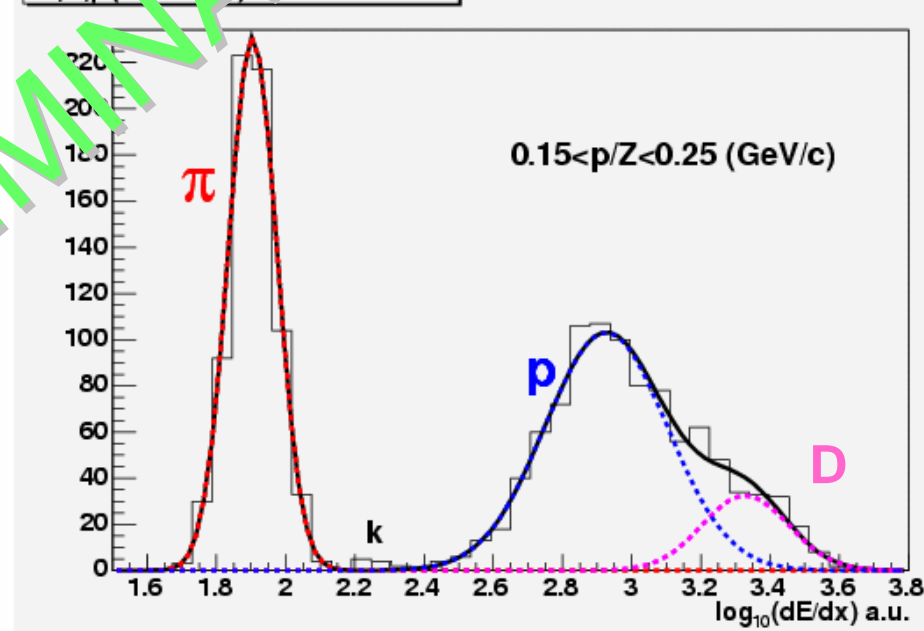
RICH Ring Radii



$\pi, k, p (+20 \text{ GeV}) + \text{Carbon } 2\%$



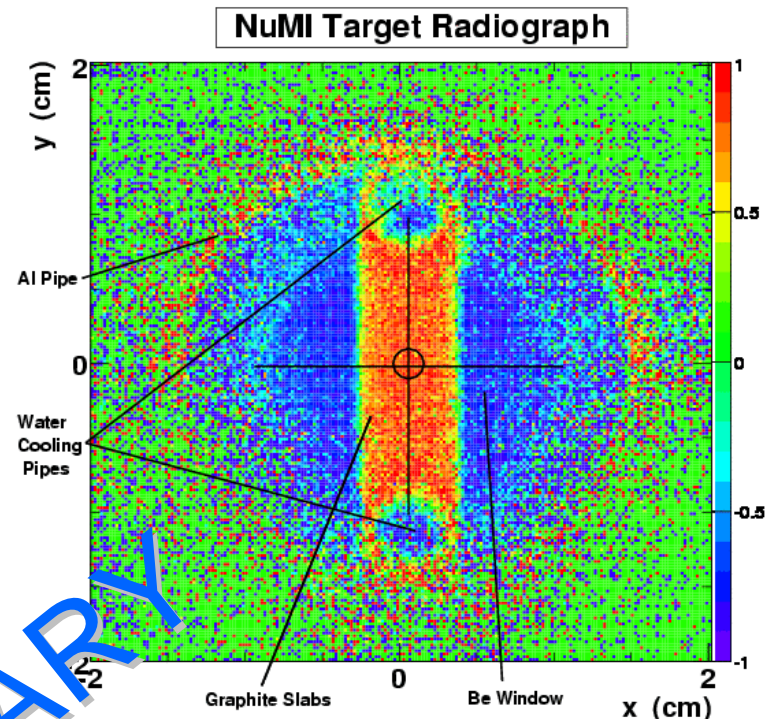
$\pi, k, p (+20 \text{ GeV}) + \text{Carbon } 2\%$



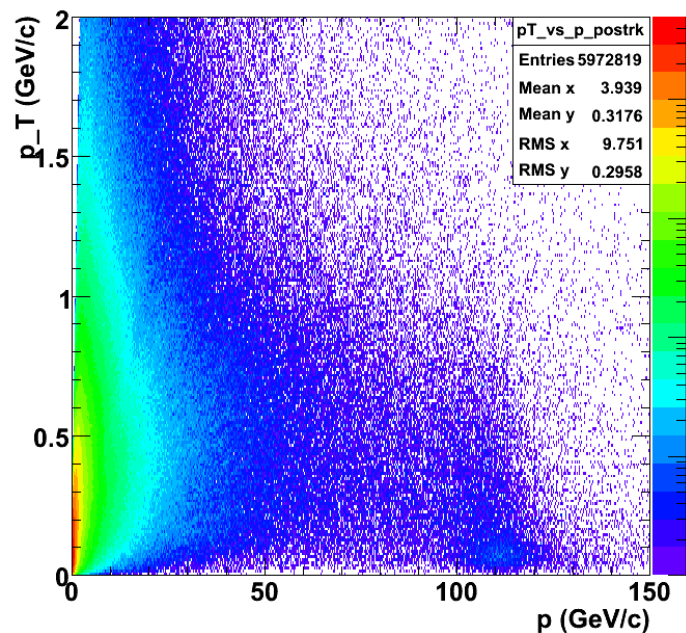


# NuMI target data

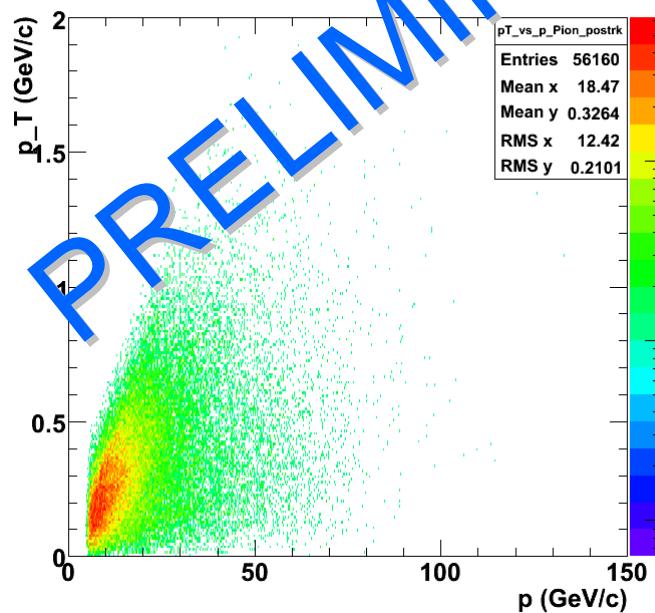
- Beam aligned  $\Delta x = 0.002$  cm  
 $\Delta y = 0.051$  cm
- Total positive tracks, Pions and Kaons identified by the RICH



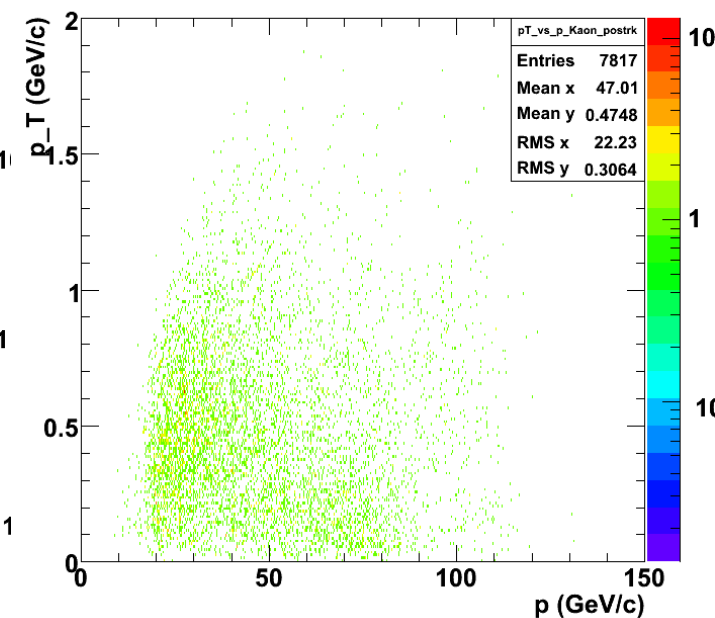
p\_T vs. p, Pos. Tracks



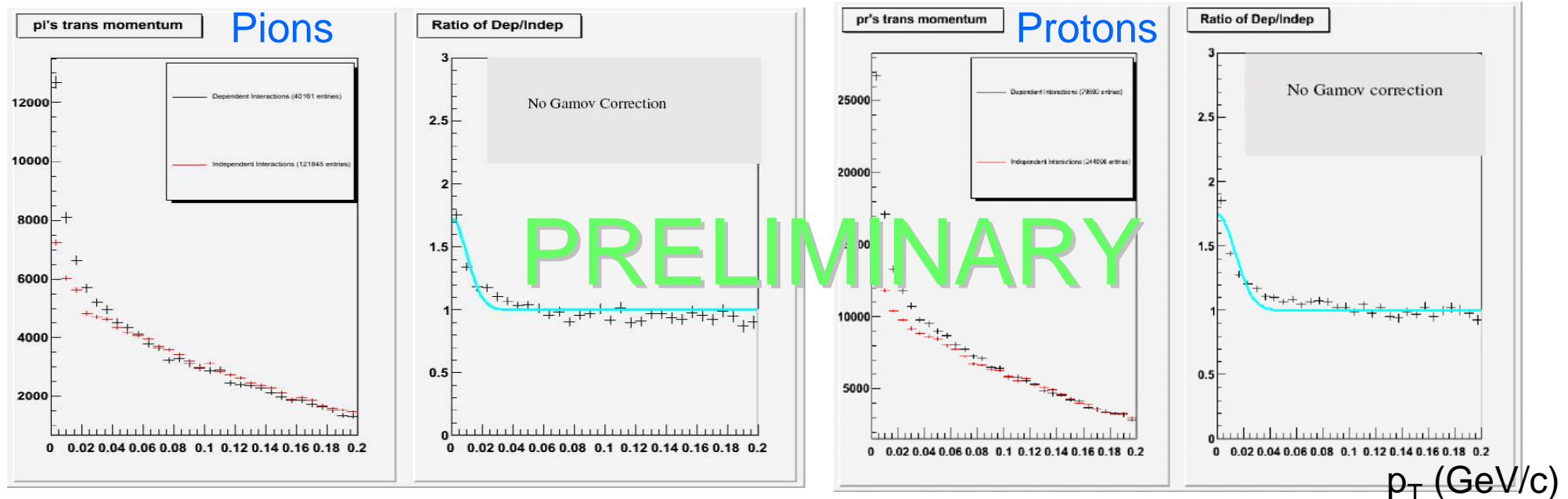
Pion p\_T vs. p, Pos. Tracks



Kaon p\_T vs. p, Pos. Tracks



# Early MIPP Physics - HBT



- HBT effect, pions preferentially emitted together
  - Plot transverse momentum between a pion and all other pions in event - Dependent
  - Compare to transverse momentum from pions in different events – Independent
  - Look for excess at low  $p_T$  in ratio of Dependent/Independent
- Seen in MIPP with Kaons and Protons too with broader peaks
- Calculate radius of particle interaction from interference peak
- Gamov correction for charge repulsion required

# MIPP upgrade

- Hard at work finishing reconstruction and analysing data but also working towards upgrade of MIPP
- Fifty fold increase in data taking rate
- Upgraded hardware
  - TPC readout electronics limit data taking – use ALICE chips
  - JGG magnet repair
  - Larger veto wall
  - Beamline optics and shielding
- Physics
  - More NuMI target statistics, NOvA target and others
  - Pi and K production cross sections on liquid nitrogen for atmospheric neutrinos
  - Higher statistics for hadron shower simulations – ILC
- Limiting factor is manpower, new collaborators welcome!